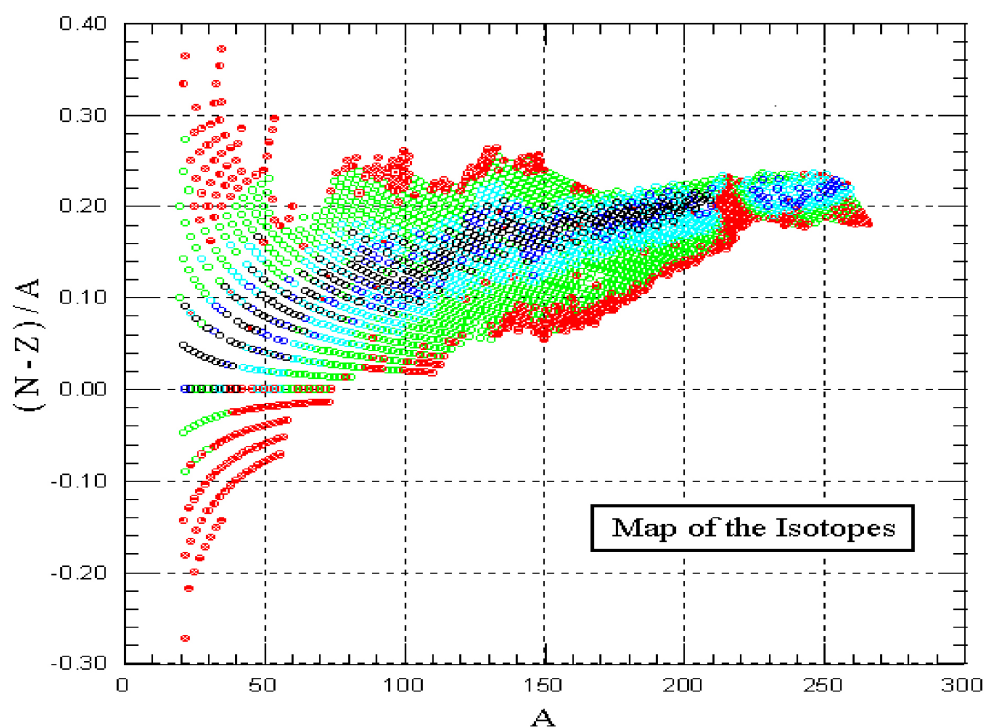


Evaluated Decay Data for ^{206}Tl

Nuclear Data and Measurements Series

Nuclear Engineering Division



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by
Filip G. Kondev
Nuclear Engineering Division, Argonne National Laboratory

December 5, 2006



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Dr. Filip G. Kondev
Nuclear Data Program
Nuclear Engineering Division
Building 208/C-162
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439, USA

Tel: +1(630)252-4484
Fax: +1(630)252-4978
E-mail: kondev@anl.gov

ANL/NDM-162

Evaluated Decay Data for ^{206}Tl *

Filip G. Kondev [#],

Nuclear Engineering Division, Argonne National Laboratory, Argonne, Illinois 60439, U.S.A.

Abstract

Evaluated decay data for the ^{206}Tl nuclide are presented, including recommended values for the half-life, β^- and γ -ray emission energies and probabilities. Data on X-ray radiations, Auger and conversion electron energies and emission probabilities are also tabulated.

* This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract DE-AC02-06CH11357.

[#] E-mail - kondev@anl.gov.

1. Introduction

Carefully evaluated data for radioactive nuclides refer to complex nuclear level schemes and tables of numerical values, which quantify fundamental nuclear structure information such as level energies and quantum numbers, lifetimes, decay modes, and other associated properties. These data are not only at the core of basic nuclear structure and nuclear astrophysics research, but they are also relevant to many applied technologies, including nuclear energy production, reactor design and safety, medical diagnostic and radiotherapy, health physics, environmental research and monitoring, safeguards and material analysis. The evaluation process results in numerous sets of recommended values on half-lives, radiation energies and emission probabilities.

The work on evaluation of decay properties of ^{206}Tl was completed in September 2006 with a literature cut off by the same date. The Saisinuc software (2002BeXX) and associated supporting programs were used in assembling the data following the established protocol within the International Decay Data Evaluation Project (DDEP) collaboration.

2. Decay Scheme

The nuclide ^{206}Tl ($J^\pi=0^-$) disintegrates 100 % by β^- emissions. The decay scheme is shown in Figure 1. The strongest β^- -decay branch of 99.885 (14) % populates the $J^\pi=0^+$ ground state of the daughter nuclide ^{206}Pb . The level schemes of ^{206}Tl and ^{206}Pb are based on the ENSDF evaluation of Browne (1999Br39).

3. Nuclear Data

$Q(\beta^-)$ value is taken from the evaluation of Audi et al (2003Au03).

The experimental half-life data for the ^{206}Tl ground state are presented in Table 1. These data were evaluated using different techniques (see for example 1992Ra08, 1994Ka08, 2004MaXX and references therein) and the results are presented in Table 2. The value of 1961Nu01 was excluded from the data analysis, since no uncertainty was quoted in the original publication. The LRSW value of $T_{1/2}=4.202$ (11) min is recommended here with $\chi^2_v=1.54$ ($\chi^2_v=\chi^2/N-1$) which is smaller than the critical value

of $\chi^2_{\text{v cryt}}=2.64$ (99% confidence level). The lifetimes of the excited states of the daughter nucleus ^{206}Pb are taken from the ENSDF evaluation of Browne (1999Br39).

3.1. β^- Transitions

The experimental data for the maximum $\beta_{0,0}$ energy, $E_{\beta_{0,0} \text{ max}}$, are presented in Table 3. The LRSW value of 1527 (3) keV ($\chi^2_{\text{v}}=1.48$ is smaller than $\chi^2_{\text{v cryt}}=4.61$ (99% confidence level)) is comparable with $Q(\beta^-)=1532.4$ (6) keV (2003Au03). The $E_{\beta \text{ max}}$ values for the $\beta_{0,1}$ and $\beta_{0,2}$ transitions were determined from $Q(\beta^-)$ (2003Au03) and the 2^+ and 0^+ level energies that were deduced from the corresponding transition energies (see section 3.2 and Table 2.2 of the Appendix for details). The $\beta_{0,1}$ and $\beta_{0,2}$ transition probabilities, P_{β} , were deduced from the decay scheme and the corresponding absolute γ -ray transition probabilities, $P_{\gamma+\text{ce}}$, as detailed in section 3.2 and Table 2.2 of the Appendix. The $P_{\beta_{0,1}}$ value is an upper limit, since the possible feeding from the 1166.4 keV level ($J^\pi=0^+$) via the yet unobserved 363.3 keV γ -ray transition ($\gamma_{2,1}$) was not taken into account. It should be noted that only a limit for $P_{\gamma_{2,1}}$ is reported in the literature (see section 3.2 for details). The $\beta_{0,0}$ transition probability was determined as:

$$P_{\beta_{0,0}} = 100 - P_{\beta_{0,1}} - P_{\beta_{0,2}}.$$

The $\log ft$ values were calculated using the LOGFT program from the ENSDF evaluation package. The $\log f$ values are based on the work of Gove and Martin (1971Go40). For the first forbidden $\beta_{0,0}$ transition ($0^- \rightarrow 0^+$) the shape factor was measured by several authors, as shown in Table 3. The fit to the experimental data using the expression $S(W) = 1 + aW + b/W$, where W is the electron energy, yields the shape factor coefficients, a and b , which are also presented in Table 3. The value of $a=-0.020$ (2) (with $b=0.000$) (1972Wi18) is recommended in the present evaluation. It should be noted that using this parameterization of the shape factor, the $\log f$ value of 2.85 for the $\beta_{0,0}$ transition ($0^- \rightarrow 0^+$) can be obtained. It is in good agreement with that of $\log f=2.78$, deduced using the LOGFT program (1971Go40).

3.2 Gamma Transitions and Electron Internal Conversion Coefficients

The γ -ray transition energies, multipolarities, absolute transition probabilities and electron internal conversion coefficients are presented in Table 2.2 of the Appendix .

The γ -ray transition multipolarities are taken from the ENSDF evaluation of Browne (1999Br39). The recommended $\gamma_{1,0}$ transition energy of 803.06 (3) keV is determined as the weighted mean of 803.10 (5) keV (1972Ma63) and 803.04 (3) keV (1996Ra16), the two most precise values reported in the literature. The $\gamma_{2,0}$ transition between the excited 0^+ level and the 0^+ ground state is a pure E0, and hence, there is no γ -ray component associated with the decay of the former level. The transition energy is taken from the work of Draper et al. (1977Dr08) where the K-shell conversion electron energy was measured with a Si(Li) detector. The $\gamma_{2,1}$ transition was not observed and its energy is inferred from the energy difference between the excited 0^+ and 2^+ levels. The electron internal conversion coefficients were calculated using a program supplied by the Saisinuc software (2002BeXX) which uses interpolated values of Band et al (2002Ba85) with the hole being taken into account. The $P_{\gamma+ce}$ values for the $\gamma_{1,0}$ and $\gamma_{2,1}$ transitions were determined from the absolute γ -ray emission probabilities, P_γ , shown in Table 4, and the total electron internal conversion coefficients as: $P_{\gamma+ce} = P_\gamma \times (1 + \alpha_T)$. Experimental and evaluated P_γ values are shown in Table 4. The LRSW value of $P_{\gamma_{1,0}}=0.0050$ (3) % ($\chi^2_{\nu}=2.40$ is smaller than $\chi^2_{\nu \text{ cryt}}=4.61$ (99% confidence level)) is recommended for the $\gamma_{1,0}$ transition. As stated above, the $\gamma_{2,1}$ transition was not observed experimentally and only a limit for its absolute emission probability was given in 1972CoYX and 1972Gr01. The value of $P_{\gamma_{2,1}} < 0.00026$ % (1972CoYX) is adopted in the present evaluation. The $\gamma_{2,0}$ transition is a pure E0 ($0^+ \rightarrow 0^+$) and hence $P_{\gamma_{2,0}}$ is zero. The recommended $P_{\gamma+ce}(\gamma_{2,0})$ value here is deduced from the measured absolute KX-ray yield, $P_{XK}(\gamma_{2,0})$, the corresponding fluorescence yield, ω_K , and the K/T conversion electrons ratio. The value of $P_{XK}(\gamma_{2,0})=0.09$ (1) %, deduced as a weighted mean of 0.08 (2)% (1972CoYX) and 0.10 (2)% (1972Gr01) (see Table 4), is adopted in the present work. It should be noted that an electron shake-off component of 0.02% has been taken into account in these values. The K-shell to total conversion electrons ratio of K/T=0.85 (6) was deduced from K/L=5.7 (4), a weighted mean of the measured K/L=5.61 (38) and 6 (1) in 1990Tr01 and 1977Dr08, respectively. This value is in very good agreement with

that of $K/T=0.855$, calculated using the electronic factors of $\Omega_K(E0)$ and $\Omega_L(E0)$ that are given by the BRICC program (2005KiZW). Using a K-fluorescence yield value of $\omega_K=0.963(4)$ (1996Sc06) one then obtains:

$$P_{\gamma+ce}(\gamma 2,0) = P_{ce}(\gamma 2,0) = (P_{KX}(\gamma 2,0) / \omega_K) / (K/T) = 0.110(14)\%$$

4. Atomic Data

The Atomic data (Fluorescence yields, X-Ray energies and Relative probabilities, and Auger electrons energies and Relative probabilities) were provided by the Saisinuc software (2002BeXX). Details regarding the origin of these data can be found in 1996Sc06, 1998ScZM, 1999ScZX, 2000ScXX and 2003DeXX.

5. Photon Emissions

5.1 X-Ray Emissions

The X-ray yield in β^- decay of ^{206}Tl is produced entirely in the decay of the 1166.4 keV ($E0, 0^+ \rightarrow 0^+$) transition. Contributions from the much weaker 803.06 and 363.3 keV transitions can be neglected, since their X-ray yields are several orders of magnitude smaller than that of the 1166.4 keV transition.

For the 1166.4 keV $E0 (0^+ \rightarrow 0^+)$ transition, the number of vacancies in the K-shell per 100 disintegrations was determined as:

$$N_K = P_{ceK} = P_{XK} / \omega_K = 0.090(10) / 0.963(4) = 0.093(11).$$

The corresponding number of vacancies in the L shell per 100 disintegrations was then determined as:

$$N_L = P_{ceL} + n_{KL} \times N_K = 0.0163(22) + 0.811(5) \times 0.093(11) = 0.092(11)\%$$

where $P_{ceL} = P_{ceK} / (K/L) = 0.0163(22)\%$ with $K/L=5.7(4)$, a weighted mean of 5.61 (38) (1990Tr01) and 6 (1) (1977Dr08). The number of X-rays per 100 disintegrations was then calculated as:

$$P_{XK} = \omega_K \times N_K \text{ and } P_{XL} = \tilde{\omega}_L \times N_L$$

5.2 Gamma Emissions

The number of γ rays per 100 disintegrations was evaluated from the available experimental data, as described in section 3.2 (see also Table 4).

6. Electron Emissions

The energies of the conversion electrons were calculated from the γ -ray transition energies presented in Table 2.2 of the Appendix and the corresponding electron shell binding energies (1977La19). For the $\gamma_{1,0}$ transition, the number of conversion electrons of type $x=T,L,M,N$ and O , where T stands for total, L for L -shell electrons, etc., per 100 disintegrations was calculated from the absolute photon intensity ($P_{\gamma_{1,0}}$ per 100 disintegrations) recommended in the present evaluation (see Table 4), and the corresponding electron internal conversion coefficients (see Table 2.2 of the Appendix), $\alpha_{x1,0}$: $ec_{1,0x} = P_{\gamma_{1,0}} \times \alpha_{x1,0}$. For the $\gamma_{2,0}$ transition, the number of K and L conversion electrons per 100 disintegrations was determined from the measured P_{XK} yield, ω_K value and the K/L sub-shell ratio, as detailed in section 5.1.

The number of K and L Auger electrons per 100 disintegrations, $P(e_{AK(L)})$ was calculated from the number of vacancies in the K and L shells and the corresponding $P_{XK(L)}$ yield: $P(e_{AK}) = N_K - P_{XK}$ and $P(e_{AL}) = N_L - P_{XL}$.

7. Acknowledgment

This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract DE-AC02-06CH11357. It was undertaken with the assistance of the Nuclear Data Section of the International Atomic Energy Agency, and under the auspices of the IAEA Coordinated Research Project "Updated Decay Data Library for Actinides". The author is indebted to Dr. M.M. Be (LNHB) and Dr. E. Browne (LBNL) for many useful discussions on various aspects of this work. The author is also grateful to Dr. I. Ahmad (ANL) for his critical reading of the manuscript and useful comments.

8. References

- 1941Fa04 K. Fajans and A.F. Voigt, Phys. Rev. 60 (1941) 619.
(Half-life)
- 1951Al14 D.E. Alburger and G. Friedlander, Phys. Rev. 82 (1951) 977.
(Maximum β^- -decay energy)
- 1953Sa11 B.W. Sargent, L. Yaffe and A.P. Gray, Can. J. Phys. 31 (1953) 235.
(Half-life)
- 1959Po64 A. Poularikas and R.W. Fink, Phys. Rev. 115 (1959) 989.
(Half-life)
- 1961Ho17 D.A. Howe and L.M. Langer, Phys. Rev. 124 (1961) 519.
(Maximum β^- -decay energy)
- 1961Nu01 M. Nurmiä, P. Kauranen, M. Karras, A. Siivola, A. Isola, G.Graeffe and A. Lyyjy, Nature 190 (1961) 427.
(Half-life)
- 1968Zo02 W.H. Zoller, C. Botteron and W.B. Walters, MIT-905-133 (1968) p.4.
(γ -ray emission probability)
- 1970Zo02 W.H. Zoller and W.B. Walters, J. Inorg. Nucl. Chem. 32 (1970) 2465.
(γ -ray emission probability)
- 1970Fl12 D. Flothmann, R. Lohken, W. Wiesner and H. Rebel, Phys. Rev. Lett. 25 (1970) 1719.
(Half-life, Maximum β^- -decay energy)
- 1971Go40 N.B. Gove and N.J. Martin, Nuclear Data Tables 10 (1971) 205.
(log ft values)
- 1971Pe03 B.I. Persson, I. Plessner and J.W. Sunier, Nucl. Phys. A167 (1971) 470.
(Half-life, Maximum β^- -decay energy)
- 1972CoYX L.L. Collins, G.D. O'Kelley and E. Eichler, ORNL-4791 (1972) p.14.
(Half-life)
- 1972Gr01 H.C. Griffin and A.M. Donne, Phys. Rev. Lett. 28 (1972) 107.
(Half-life)
- 1972Ma63 J.C. Manthuruthil, D.C. Camp, A.V. Ramayya, J.H. Hamilton, J.J. Pinajian and J.W. Doornebos, Phys. Rev. C6 (1972) 1870.
(Gamma-ray transition energies)
- 1972Wi18 W. Wiesner, D. Flothmann, H.J. Gils, R. Lohken, H. Rebel, Nucl. Phys. A191 (1972) 166.
(Half-life, Maximum β^- -decay energy)
- 1977Dr08 J.E. Draper, R.J. McDonald and N.S.P. King, Phys. Rev. C16 (1977) 1594.
(Transition energies, K/L conversion electrons subshell ratio)
- 1977La19 F.P. Larkins, Atomic Data and Nuclear Data Tables. 20 (1977) 313.
(Electron shells binding energies)
- 1990Tr01 W.H. Trzaska, J. Kantele, R. Julin, J. Kumpulainen, P. Van Duppen, M. Huyse and J. Wauters, Z. Phys. A335 (1990) 475.
(K/L conversion electrons subshell ratio)

- 1992Ra08 M.U. Rajput and T.D. MacMahon, Nucl. Instrum. Methods Phys. Res. A312 (1992) 289.
(Evaluation techniques)
- 1994Ka08 S.I.Kafala, T.D.MacMahon and P.W.Gray, Nucl. Instrum. Methods Phys. Res. A339 (1994) 151.
(Evaluation techniques)
- 1996Ra16 S. Raman, J.B. McGrory, E.T. Journey and J.W. Starner, Phys. Rev. C53 (1996) 2732.
(Gamma-ray transition energies)
- 1996Sc06 E. Schönfeld and H. Janßen, Nucl. Instrum. Methods Phys. Res. A369 (1996) 527.
(Fluorescence yields)
- 1998ScZM E. Schönfeld and G. Rodloff, PTB-6.11-98-1, Braunschweig, Germany, October 1998
(K Auger electron energies)
- 1999Br39 E. Browne, Nucl. Data Sheets 88 (1999) 29.
(²⁰⁶Tl and ²⁰⁶Pb level schemes)
- 1999ScZX E. Schonfeld and G. Rodloff, PTB-6.11-1999-1, Braunschweig, Germany, February 1999
(KX-ray energies and relative emission probabilities)
- 2000ScXX E. Schönfeld and H. Janßen, Appl. Rad. Isot. 52 (2000) 595.
(Program Emission)
- 2002Ba85 I.M. Band, M.B. Trzhaskovskaya, C.W. Nestor, P.O. Tikkanen and S. Raman, At. Data Nucl. Data Tables. 91 (2002) 1.
(ICC)
- 2002BeXX M. Be, R. Helmer and V. Chiste, J. Nucl. Scien. and Techn., suppl. 2 (2002) 481.
(Saisinuc & supporting software)
- 2003Au03 G.Audi and A.H. Wapstra, Nucl. Phys. A729 (2003) 337.
(Decay Q values)
- 2003DeXX R.D. Deslattes, E.G. Kessler, P. Indelicato, L. De Billy, E. Lindroth and J. Anton, Rev. Mod. Phys. 77 (2003) 35.
(K and L X-ray energies)
- 2004MaXX D. MacMahon, A. Pearce and P. Harris, Appl. Rad. Isot. 60 (2004) 275.
(Evaluation techniques)
- 2005KiZW T. Kibedi, T.W. Burrows, M.B. Trzhaskovskaya and C.W. Nestor, Jr., Proc. Intern. Conf. Nuclear Data for Science and Technology, Santa Fe, New Mexico, 26 September-1 October, 2004, R.C. Haight, M.B. Chadwick, T. Kawano, P. Talou, Eds., AIP Conf. Proc. 769 (2005) 268.
(ICC)

Table 1. Experimental data for the half-life of ^{206}Tl

Author	$T_{1/2}$, min	Used in the evaluation
1941Fa04	4.23 (3)	Yes
1953Sa11	4.19 (2)	Yes
1959Po64	4.29 (5)	Yes
1961Nu01	4.2	No
1970Fl12	4.27 (5)	Yes
1971Pe03	4.183 (17)	Yes
1972CoYX	4.14 (5)	Yes
1972Gr01	4.2 (2)	Yes
1972Wi18	4.27 (5)	Yes

Table 2. Evaluated values for the half-life of ^{206}Tl

Method/Author ^{a)}	Evaluated $T_{1/2}$, min	$\chi^2/\text{N}-1$
UWM	4.222 (19)	2.02
WM	4.202 (11)	1.54
LRSW	4.202 (11)	1.54
NRM	4.202 (11)	1.54
RM	4.202 (11)	1.41
1999Br39	4.200 (17)	

^{a)} UWM – Unweighted Mean; WM – Weighted Mean; LRSW – Limitation of Relative Statistical Weight; NRM – Normalized Residual; RM – Rajeval.

Table 3. Measured $E_{\beta 0,0 \max}$ values and shape factor parameters a and b ($S(W)=1+aW+b/W$) for the first forbidden $0^- \rightarrow 0^+$ decay of ^{206}Tl

Author	a	b	$E_{\beta 0,0 \max}$, keV	Used in the evaluation
1951Al14			1510 (10)	No
1961Ho17	-0.154	-0.484	1571 (10)	No
1970Fl12	-0.017 (5)	0.030 (9)	1523 (4)	Yes
1971Pe03	0.00 (1)	0.00	1534 (5)	Yes
1972Wi18	-0.020 (2)	0.000	1527 (4)	Yes
Adopted	-0.020 (2)	0.000	1532.4 (6)	

Table 4 Experimental and evaluated γ -ray emission probabilities.

Authors	$P_{\gamma 1,0}$, %	$P_{\text{XK}}(\gamma 2,0)$ %^{a)}	$P_{\gamma 2,1}$, %	Comment^{b)}
1968Zo02	0.0055 (5)			Not used
1970Zo02	0.0055 (4)			Expt.
1972CoYX	0.0041 (6)	0.08 (2)	<0.00026	Expt.
1972Gr01	0.004 (1)	0.10 (2)	<0.001	Expt.
Adopted	0.0050 (3)	0.09 (1)	<0.00026	Evaluated

^{a)} Absolute KX-ray yield

^{b)} Expt. – experimental value used in the present evaluation. The 1968Zo02 value is superseded by 1970Zo02

Appendix

Recommended Decay Data for ^{206}Tl

1. DECAY SCHEME

^{206}Tl disintegrates 100% by β^- emissions. The strongest β^- -decay branch of 99.885 (14) % populates the ^{206}Pb ground state, while the excited 2^+ and 0^+ states are weakly populated with intensities of 0.0051 (3) % and 0.110 (14) %, respectively.

2. NUCLEAR DATA

$Q^- (^{206}\text{Tl})$: 1532.4 (6) keV

$T_{1/2} (^{206}\text{Tl})$: 4.202 (11) min

2.1. β^- Transitions

	Energy, keV	Probability $\times 100$	Nature	$\log ft$
$\beta_{0,0}$	1532.4 (6)	99.885 (14)	First forbidden	5.1775 (13)
$\beta_{0,1}$	729.3 (6)	0.0051 (3)	First forbidden Unique	8.60^{1U} (3)
$\beta_{0,2}$	366.0 (8)	0.110 (14)	First forbidden	5.99 (6)

2.2. Gamma Transitions and Internal Conversion Coefficients

	Energy, keV	$P_{\gamma+ce}$ $\times 100$	Multi- polarity	α_K	α_L	α_M	α_N	α_T
$\gamma_{1,0}$	803.06 (3)	0.0051 (3)	E2	0.00801 (24)	0.00174 (5)	$4.19 (13)10^{-4}$	$1.06 (3)10^{-4}$	0.0103 (3)
$\gamma_{2,1}$	363.3 (5)	$<2.810^{-4}$	(E2)	0.0414 (12)	0.0187 (6)	0.00476 (14)	0.00120 (4)	0.066 (2)
$\gamma_{2,0}$	1166.4 (5)	0.110 (14)	E0					

3. ATOMIC DATA Pb (Z=82)

3.1 Fluorescence yields

ω_K : 0.963 (4)
 ω_L : 0.379 (15)
 η_{KL} : 0.811 (5)

3.2 X-Ray Radiations

	Energy, keV	Relative probability
X _K (Pb)		
Kα ₂ (Pb)	72.8049	59.5
Kα ₁ (Pb)	74.9700	100
Kβ ₃ (Pb)	84.451	} 36.2
Kβ ₁ (Pb)	84.937	
Kβ ₅ (Pb)	85.47	
Kβ ₂ (Pb)	87.238	} 10.3
Kβ ₄ (Pb)	87.58	
KO _{2,3} (Pb)	87.911	
X _L (Pb)		
L _I (Pb)	9.186	
Lα (Pb)	10.4495 – 10.5512	
Lη (Pb)	11.3495	
Lβ (Pb)	12.1443 – 12.7953	
Lγ (Pb)	14.3078 – 15.2169	

3.3. Auger Electrons

	Energy keV	Relative probability
$e_{AK}(\text{Pb})$		
KLL (Pb)	56.028 – 61.669	100
KLX (Pb)	68.181 – 74.969	55.8
KXY (Pb)	80.3 – 88.0	7.78
$e_{AL}(\text{Pb})$	0.23 – 15.8198	

4. Photon Emissions

4.1. X-Ray Emissions

	Energy, keV	Number of photons per 100 disintegrations
X _K (Pb)		0.090 (10)
K α_2 (Pb)	72.8049	0.026 (3)
K α_1 (Pb)	74.9700	0.044(5)
K β_3 (Pb)	84.451 }	
K β_1 (Pb)	84.937 }	0.0150 (17)
K β_5 (Pb)	85.47 }	
K β_2 (Pb)	87.238 }	
K β_4 (Pb)	87.58 }	0.0045 (6)
KO _{2,3} (Pb)	87.911 }	
X _L (Pb)		0.035 (4)

4.2 Gamma Emissions

	Energy, keV	Number of photons per 100 disintegrations
$\gamma_{1,0}$ (Pb)	803.06 (3)	0.0050 (3)
$\gamma_{2,1}$ (Pb)	363.3 (5)	<0.00026
$\gamma_{2,0}$ (Pb)	1166.4 (2)	0

5. Electron Emissions

		Energy, keV	Number of electrons per 100 disintegrations
e _{AK}	(Pb)		0.0034 (6)
KLL	(Pb)	56.028 – 61.669	0.0021 (4)
KLX	(Pb)	68.181 – 74.969	0.00117 (19)
KXY	(Pb)	80.3 – 88.0	0.00016 (3)
e _{AL}	(Pb)		0.057 (7)
ec _{1,0 T}	(Pb)	715.04 – 803.02	5.2 (4)10 ⁻⁵
ec _{1,0 K}	(Pb)	715.04 (3)	4.0 (3)10 ⁻⁵
ec _{1,0 L}	(Pb)	787.18 – 790.0	8.7 (6)10 ⁻⁶
ec _{1,0 M}	(Pb)	799.19 – 800.56	2.1 (1)10 ⁻⁶
ec _{1,0 N}	(Pb)	802.15 – 802.9	5.3 (4)10 ⁻⁷
ec _{1,0 O}	(Pb)	802.89 – 803.02	1.03 (7)10 ⁻⁷
ec _{2,0 T}	(Pb)		0.110 (14)
ec _{2,0 K}	(Pb)	1078.40	0.093 (11)
ec _{2,0 L}	(Pb)	1150.54 – 1151.20	0.017 (3)
β _{0,0}			
	max: 1532.4 (6)		99.885 (14)
	avg: 538.86 (25)		
β _{0,1}			
	max: 729.3 (6)		0.0051 (3)
	avg: 232.39 (21)		
β _{0,2}			
	max: 366.0 (8)		0.110 (14)
	avg: 104.52 (25)		

6. Main production modes

²⁰⁵Tl(n,γ)
²¹⁰Bi α-decay
²⁰⁵Tl(d,p)
²⁰⁷Pb(t,α)
²⁰⁸Pb(d,α)

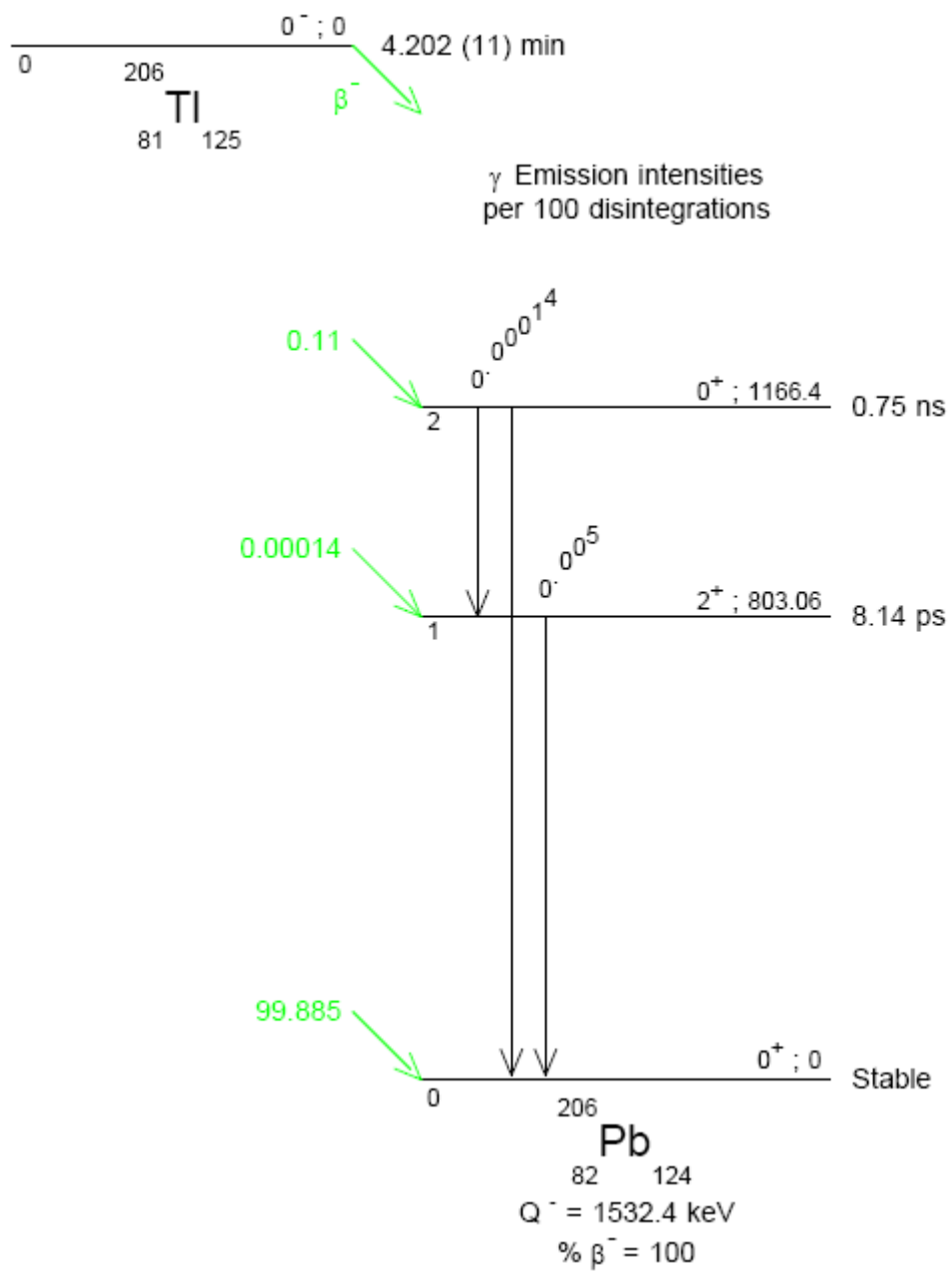


Figure 1. Decay scheme of ^{206}Tl .



Nuclear Engineering Division

Argonne National Laboratory
9700 South Cass Avenue, Bldg. 208
Argonne, IL 60439-4842

www.anl.gov



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